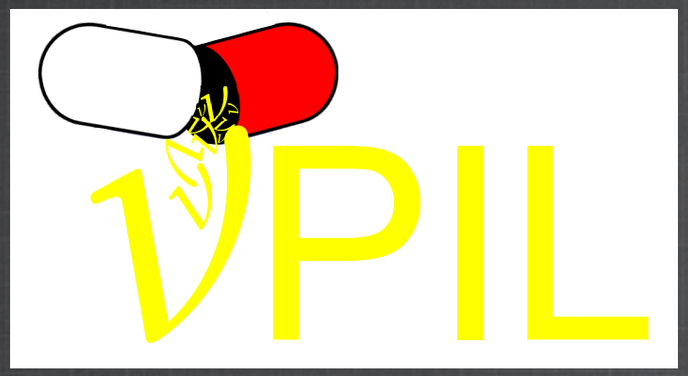

nuPIL (neutrinos from PIon beam Line)

JB. Lagrange[1,2], A. Bross[2], A. Liu[2], J. Pasternak[1]

(1): Imperial College, UK
(2): FNAL, USA

Outline

- Motivation & Concept
- Design
- Preliminary results
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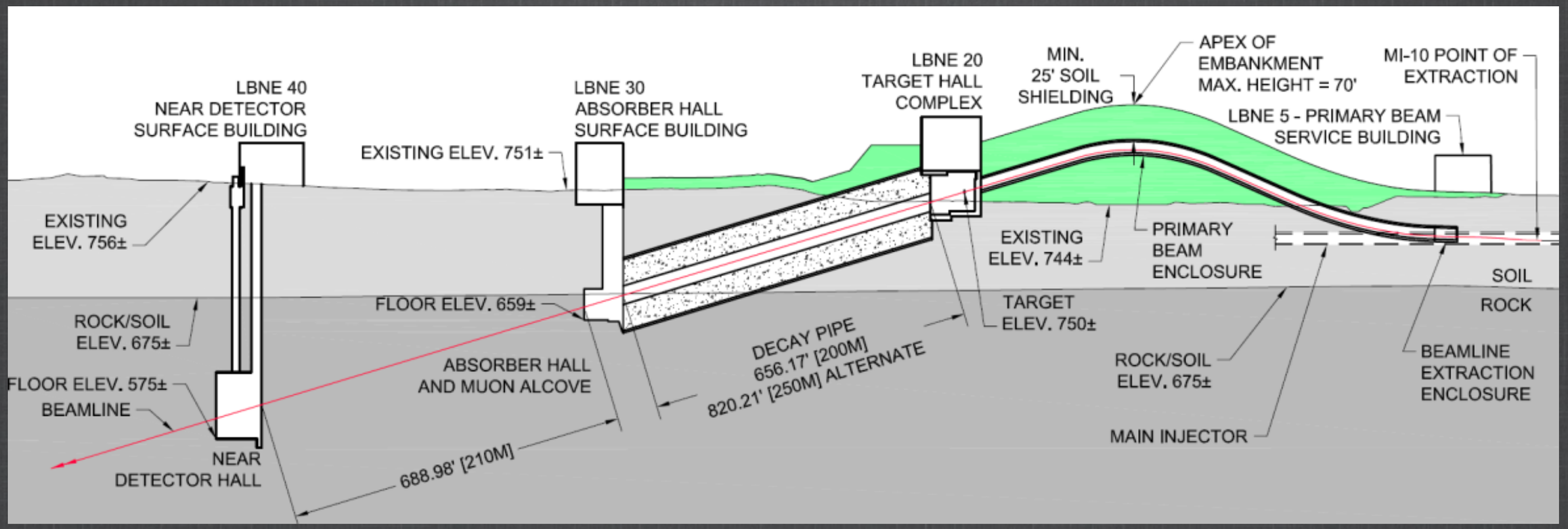
Motivation



(LBNF Letter of Intent, Jan 2015)

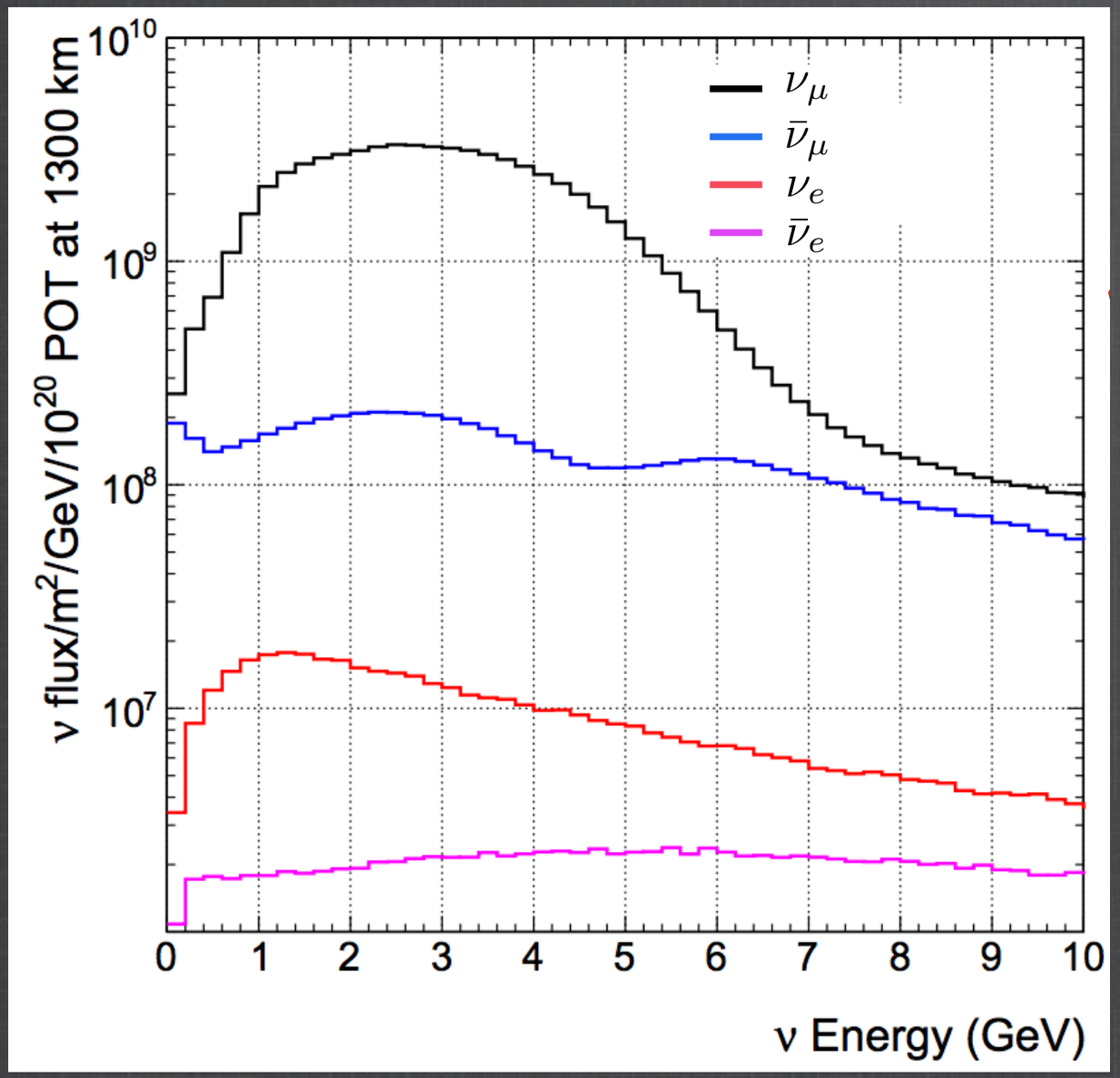
Decay pipe:

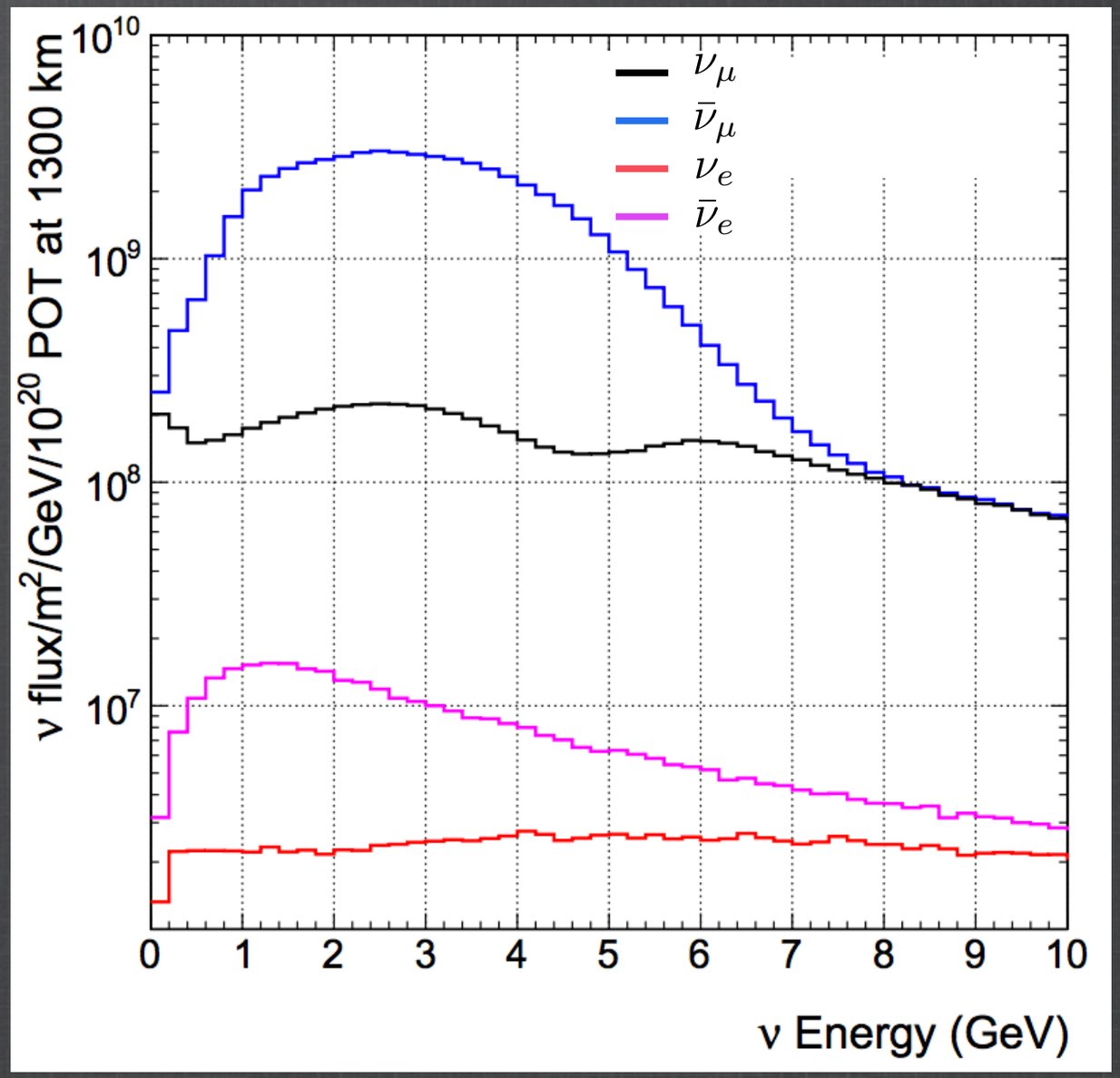
- 6 (4?) m diameter,
- filled with Helium,
- 7 m of concrete around the pipe to shield it.

→ 20 m diameter tunnel!

Neutrino Flux at DUNE

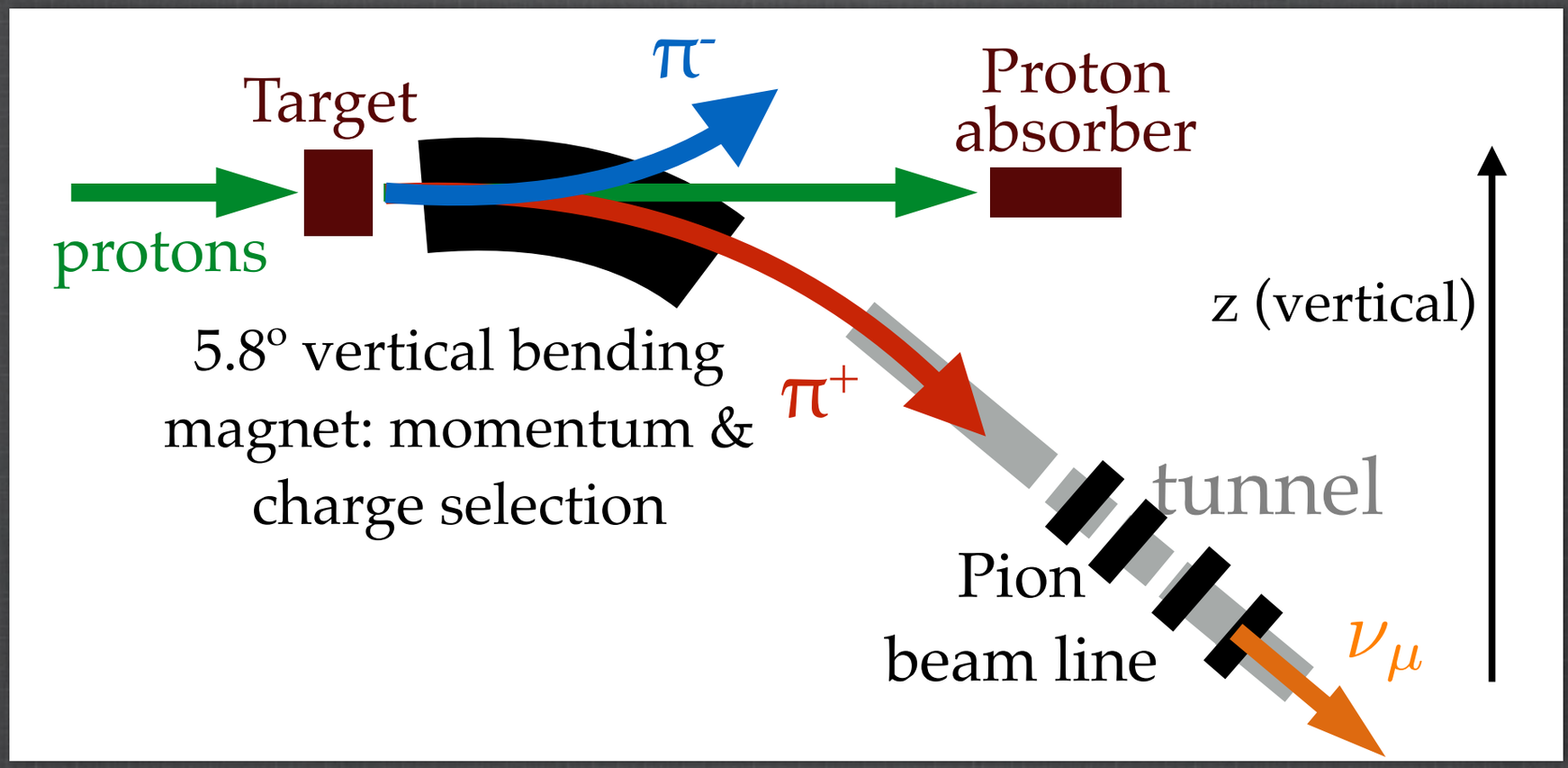
(CDR-Physics Volume)





Inevitable background from wrong-sign particles decay
(DUNE detector not magnetized: rely on high-resolution imaging to statistically discriminate neutrinos from anti-neutrinos.)

General Concept



Pion beam line

- clean, well known flux
- smaller tunnel (conventional pion beam line)
- Detector does not need to be magnetised

→ **nuPIL (Neutrinos from PIon beam Line)**

General Parameters

- Pions 7 GeV / c ± 50%
- Normal conducting range (KEK radiation hard coils)
- C-shape magnet

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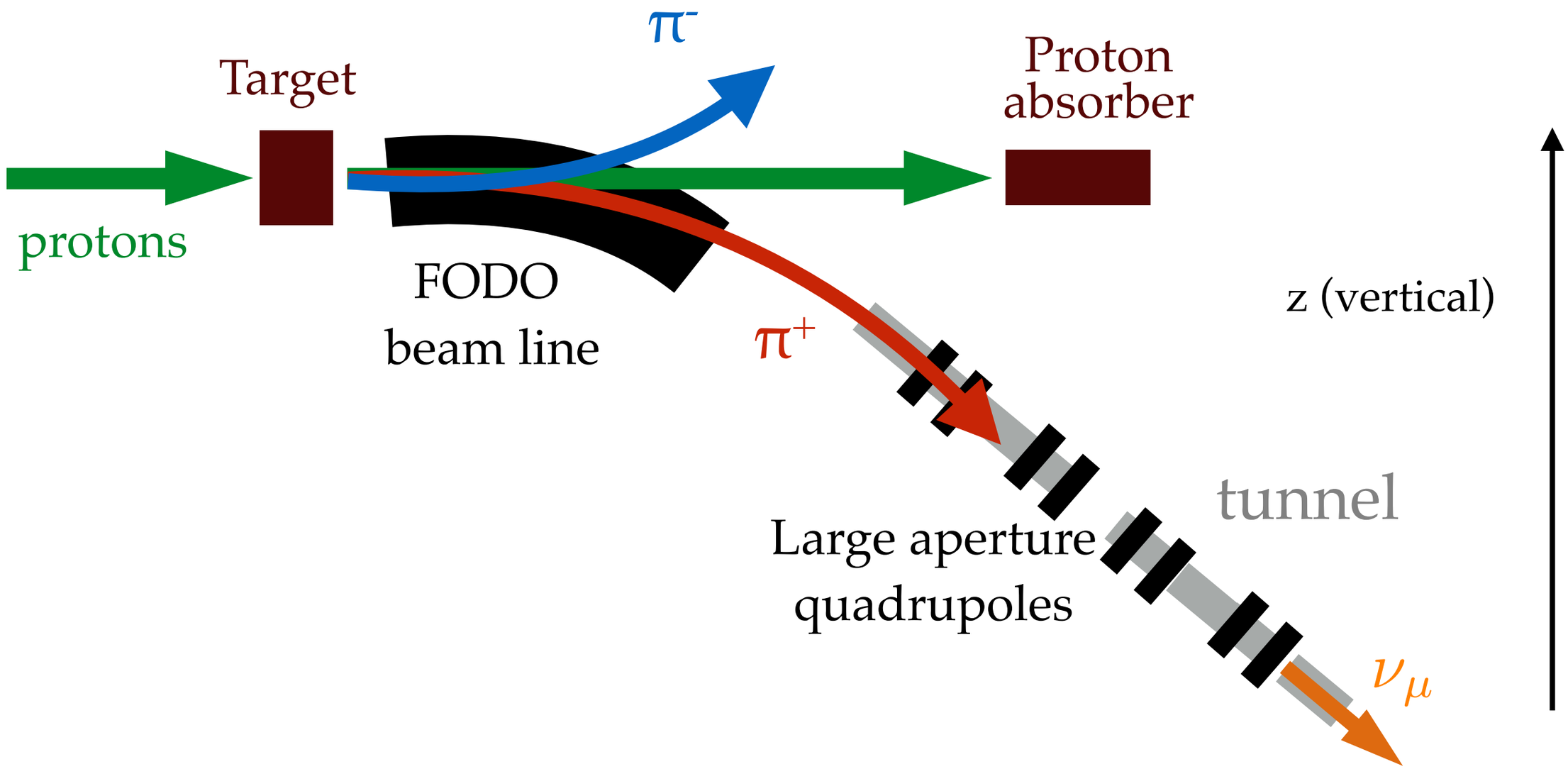
First design concept



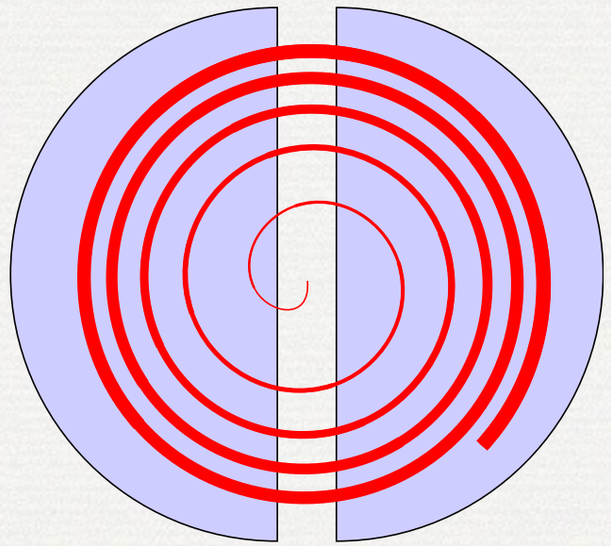
FFAG accelerator

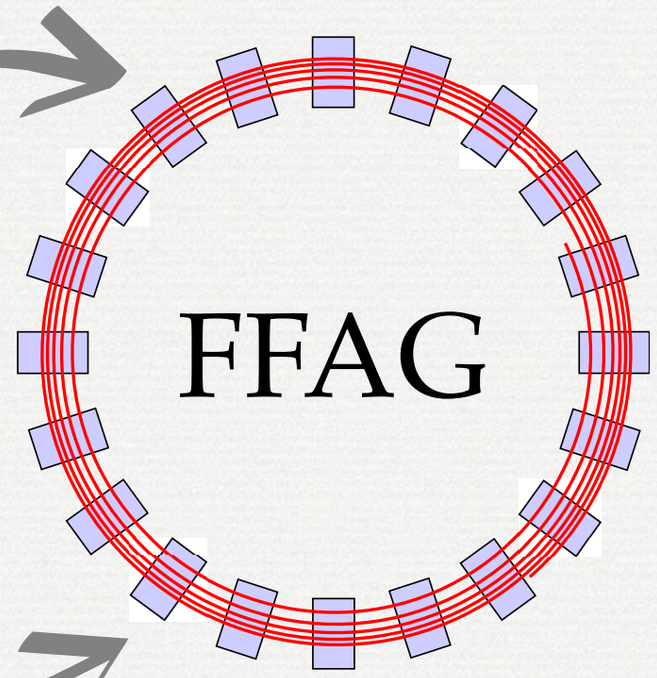
FIXED FIELD ALTERNATING GRADIENT

It combines

- **a static guide field**

like cyclotrons:

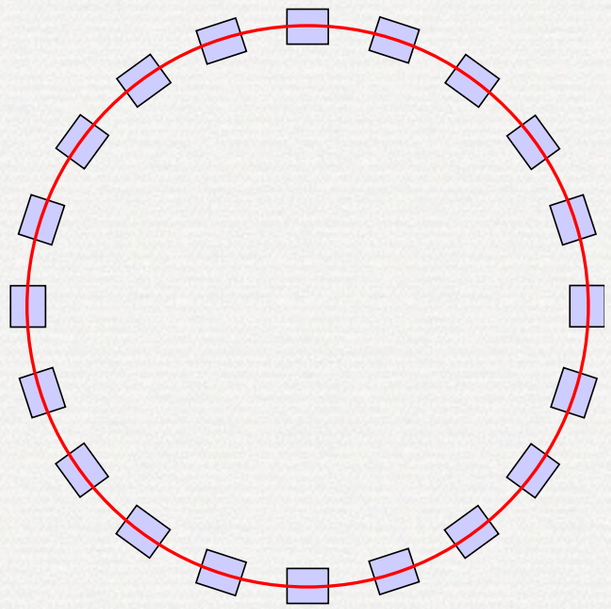




AND

- **a strong focusing**.

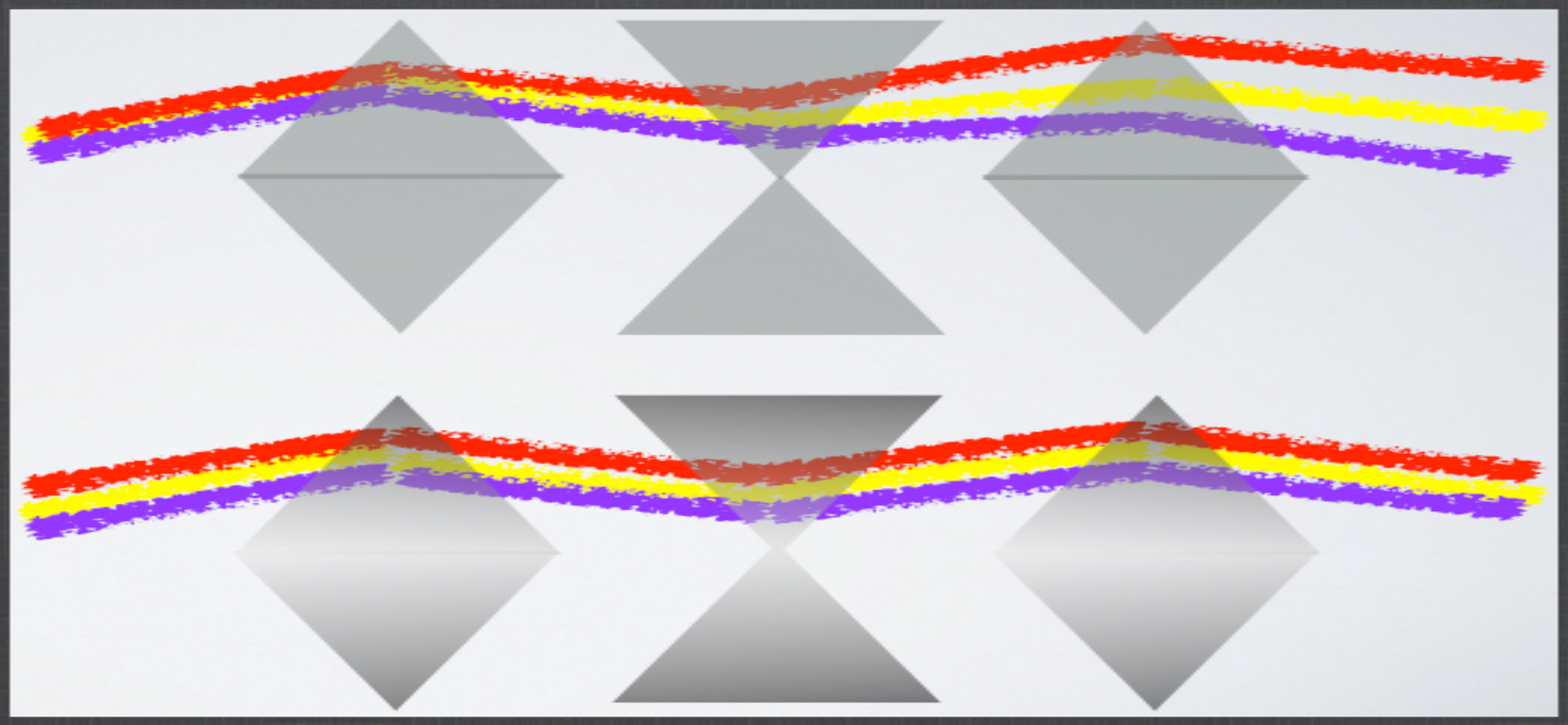
like synchrotrons:



Zero-chromatic FFAG

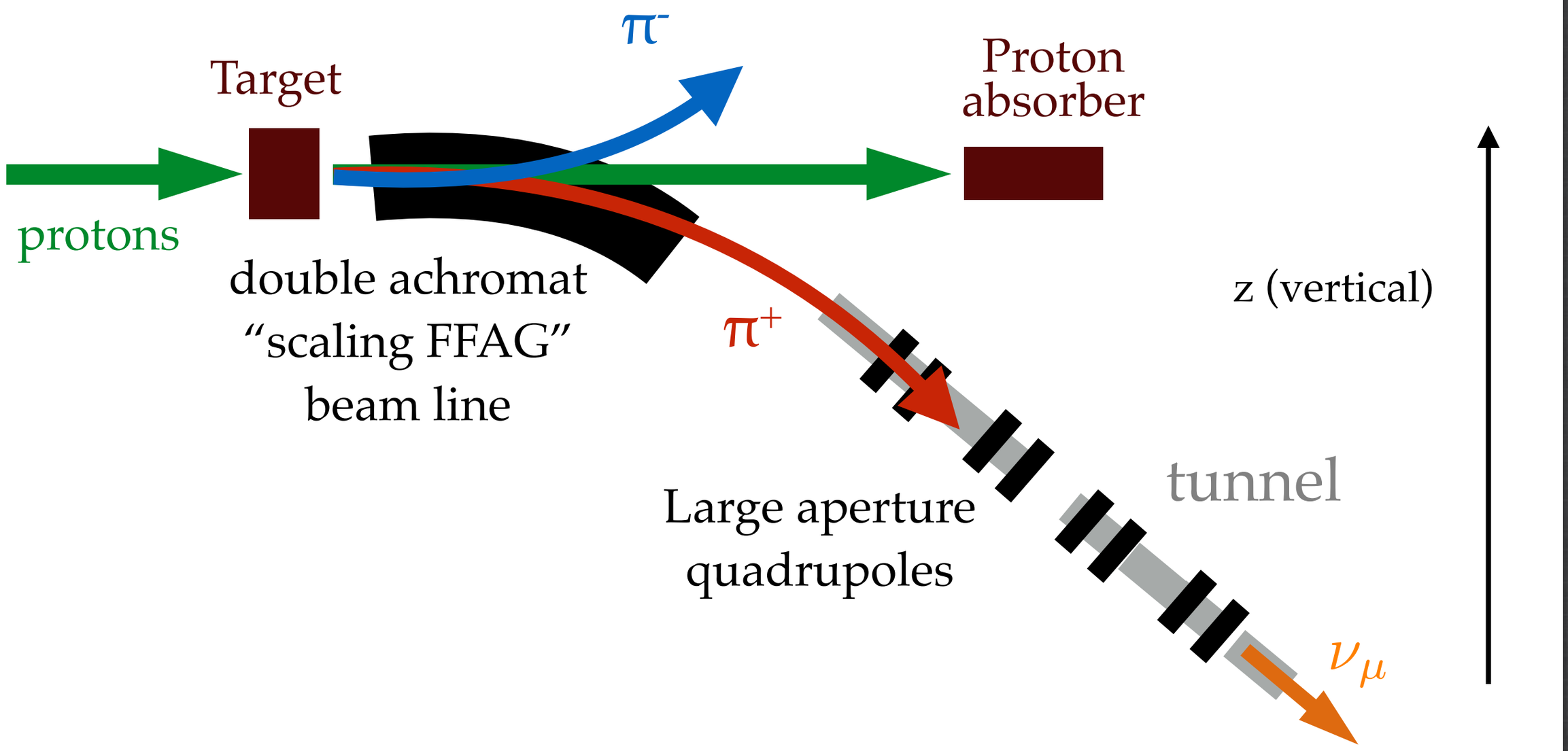
Advantages:

- stable optics for **very large momentum spread**.
- allows a good working point with a **large acceptance** far from harmful resonances.

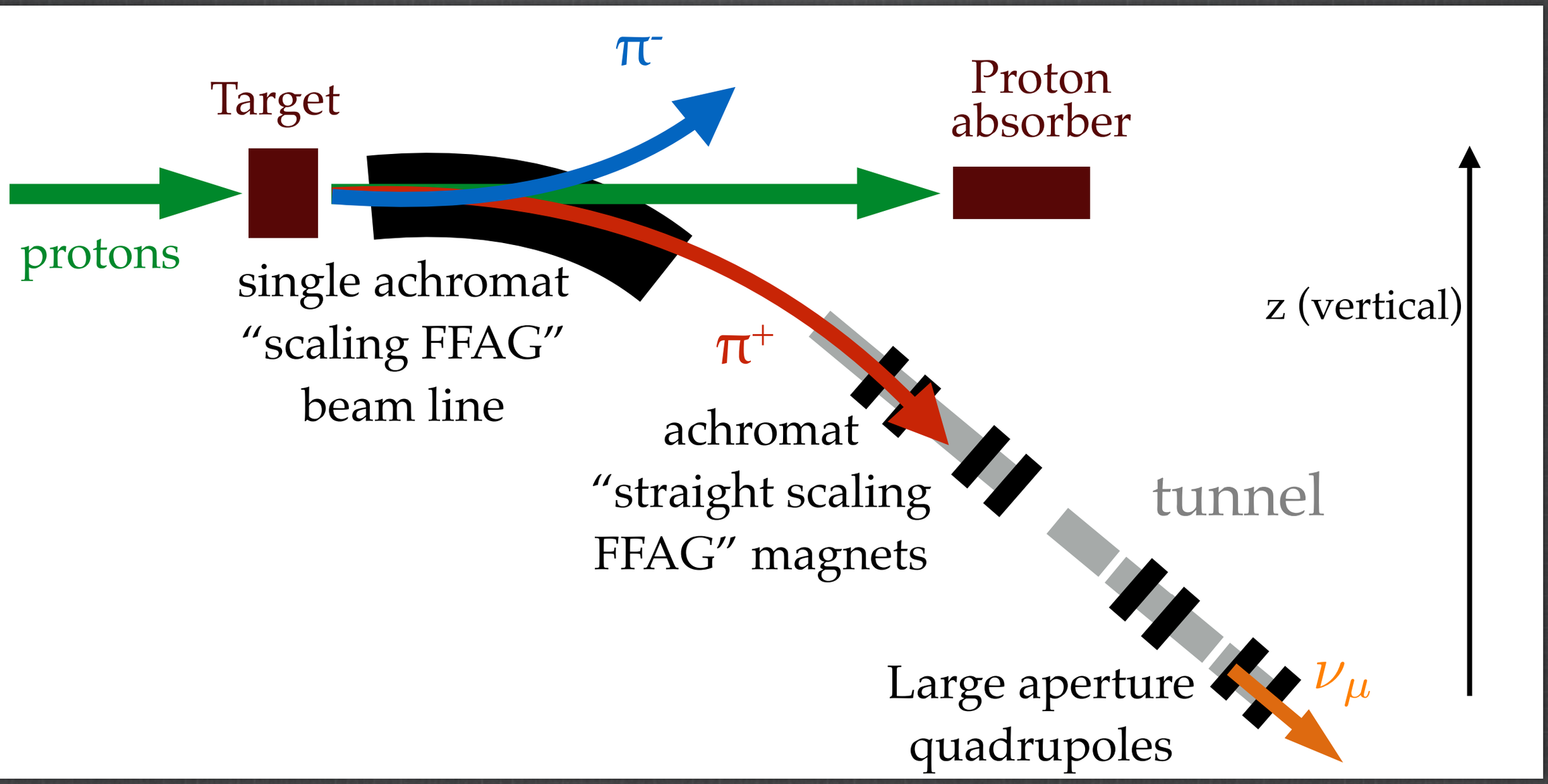


→ Quasi-zero beam loss!

Second design concept



Third design concept



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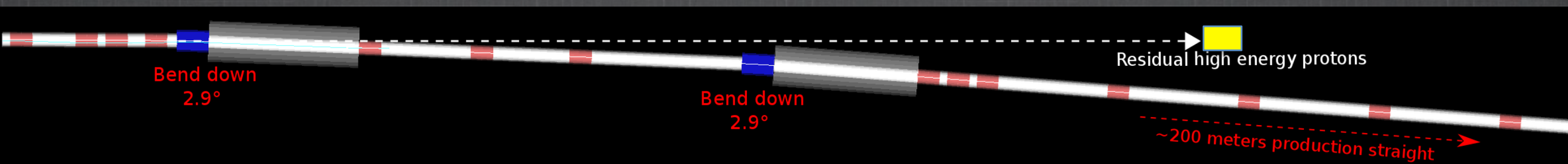
Preliminary results

No optimization yet

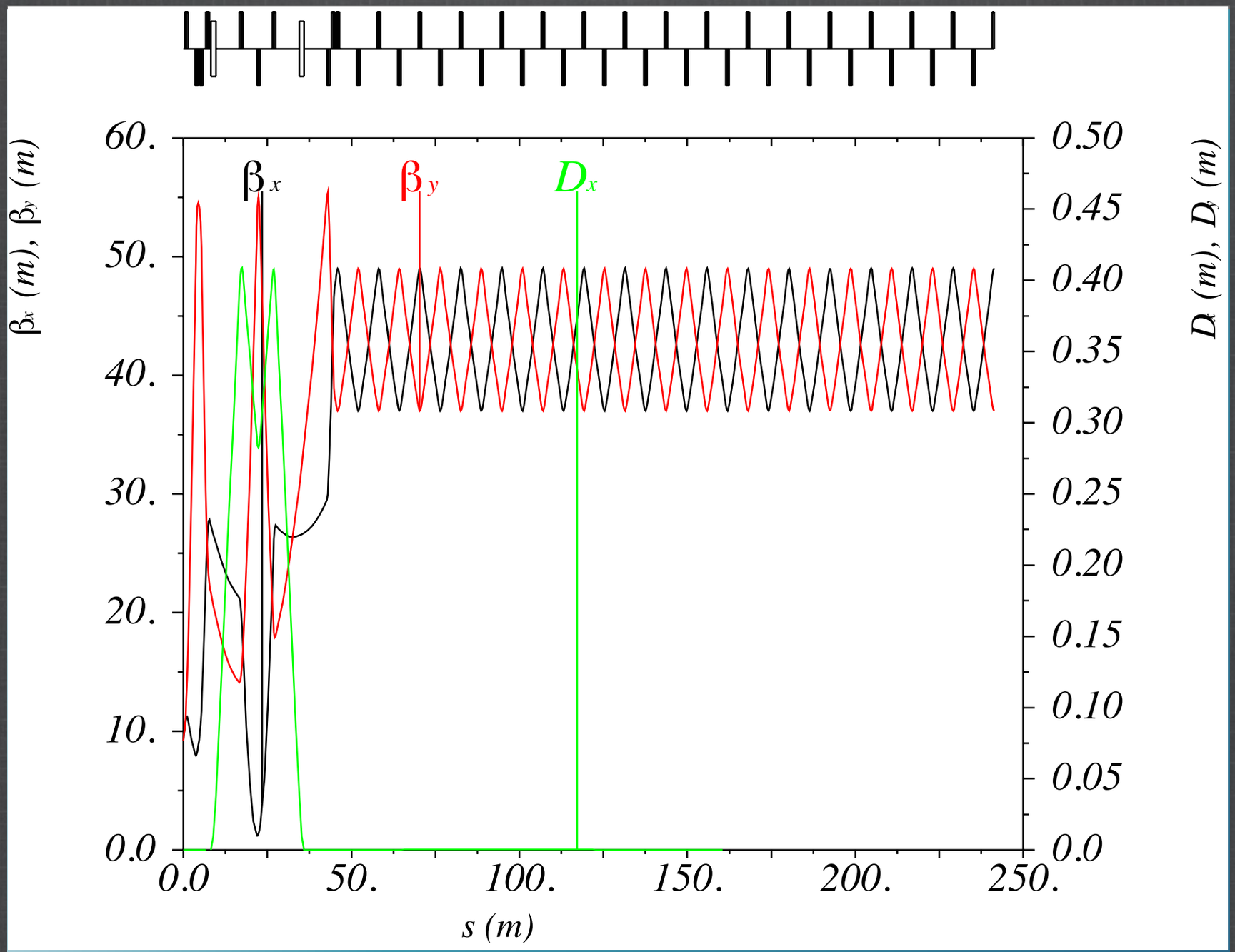
FODO beam line



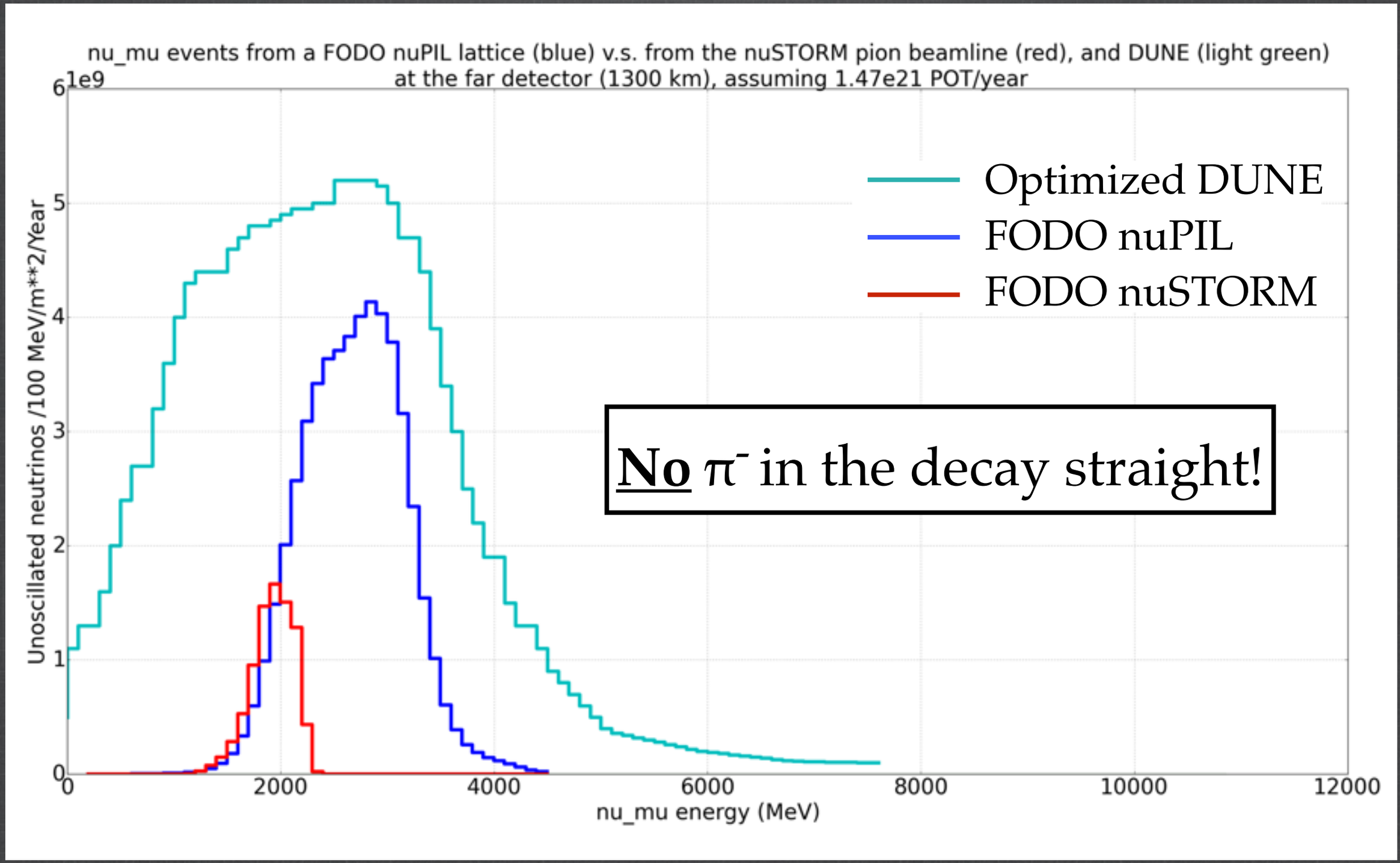
Total length 240 m.

Tracked in G4BL.

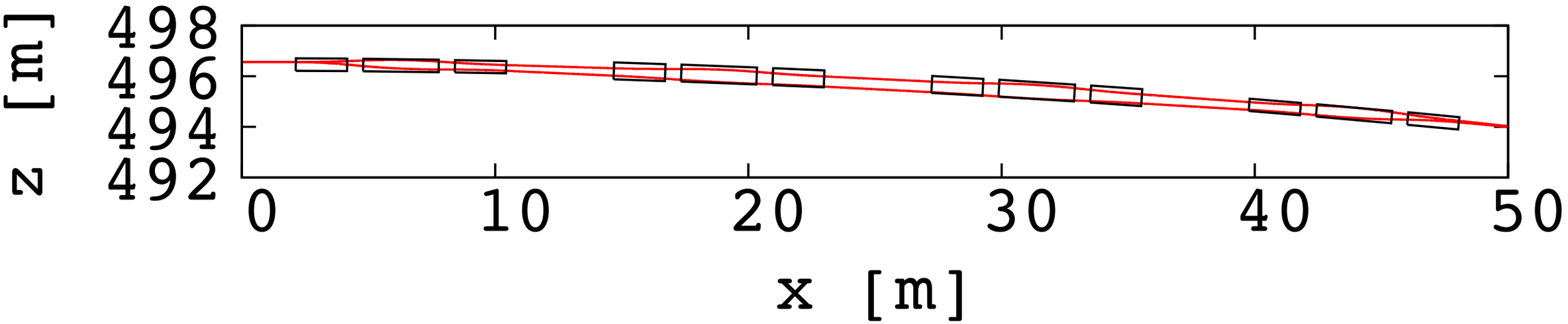
FODO beam line
Beam optics



FODO beam line Flux

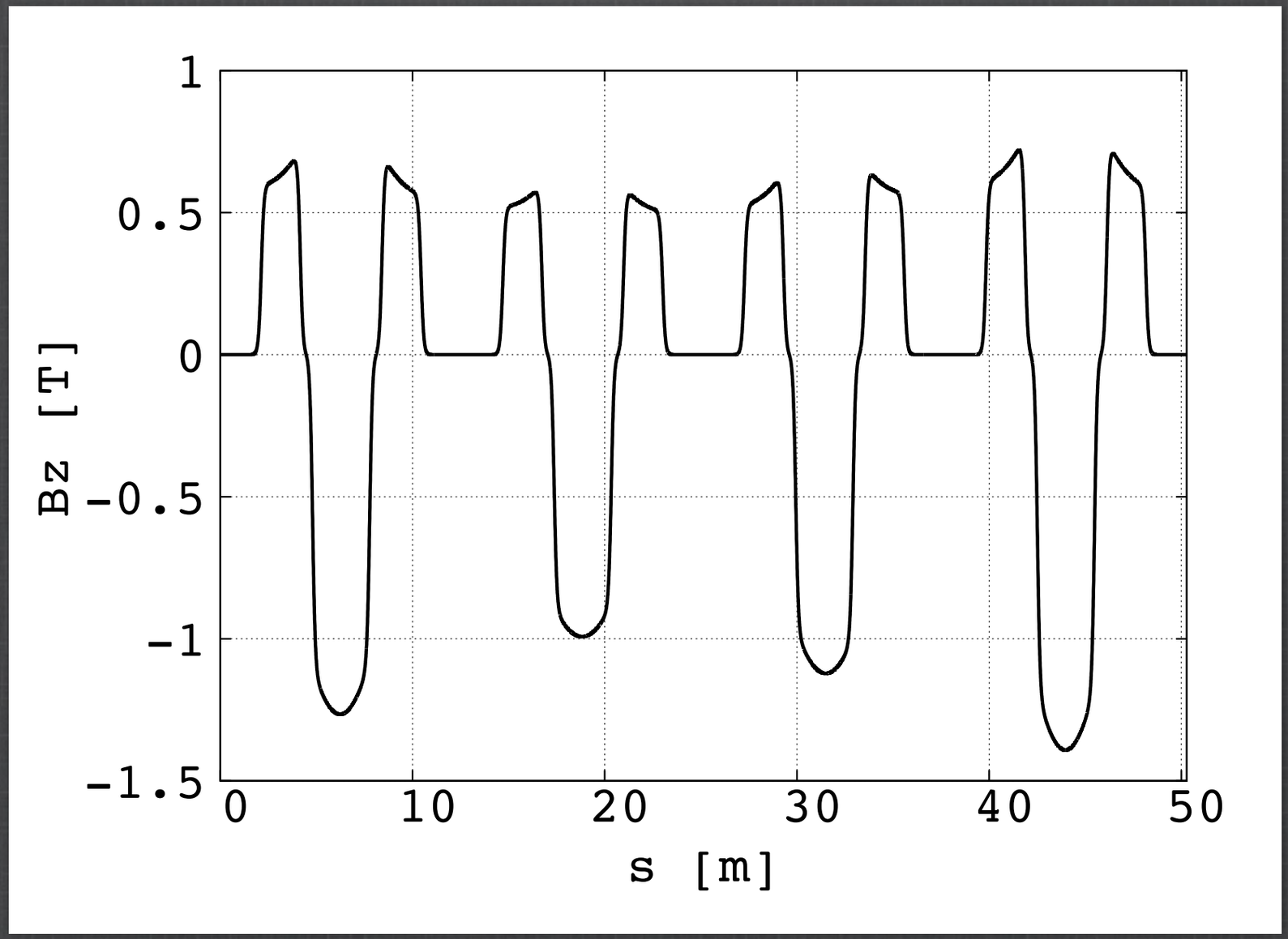


Double achromat FFAG beam line



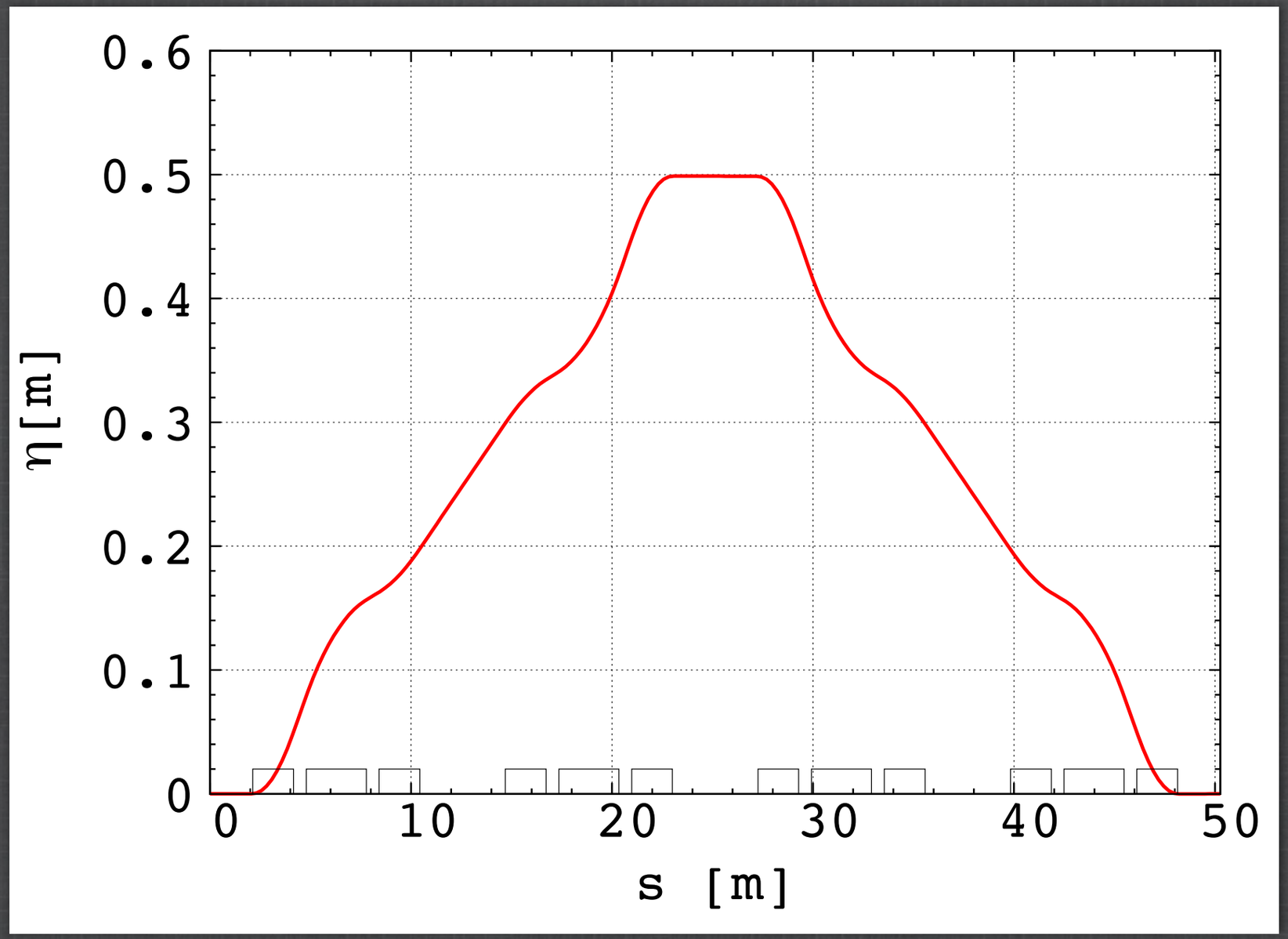
- Pions trajectories 3.5 GeV/c & 10.5 GeV/c
- Bmax < 1.7 T, excursion < 67 cm.
- k-value = 1988, r_{av} = 496.5 m, $L_{beam\ line}$ = 50 m.

Double achromat FFAG beam line



Magnetic field for P_{max} (10.5 GeV/c)

Double achromat FFAG beam line



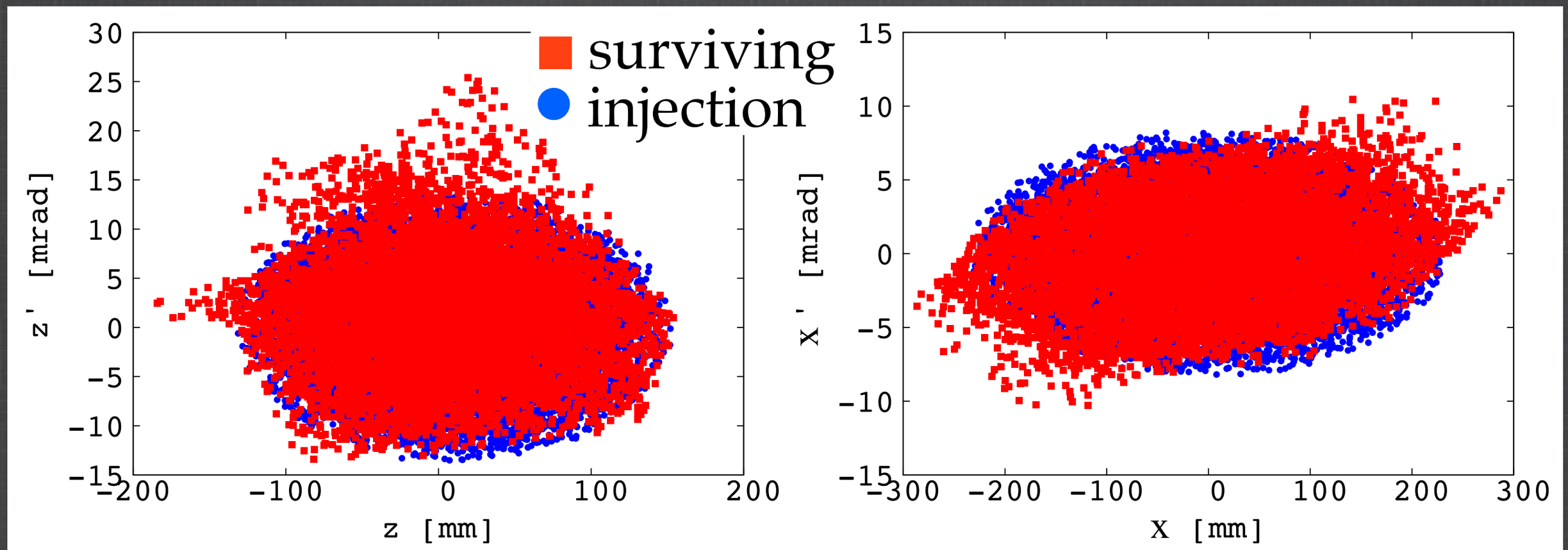
Dispersion function

double achromat FFAG beam line

Multi-particle tracking without dispersion matching.

10000 particles with a Waterbag distribution. Unnormalized emittances are **2000 π mm.mrad** in transverse planes.

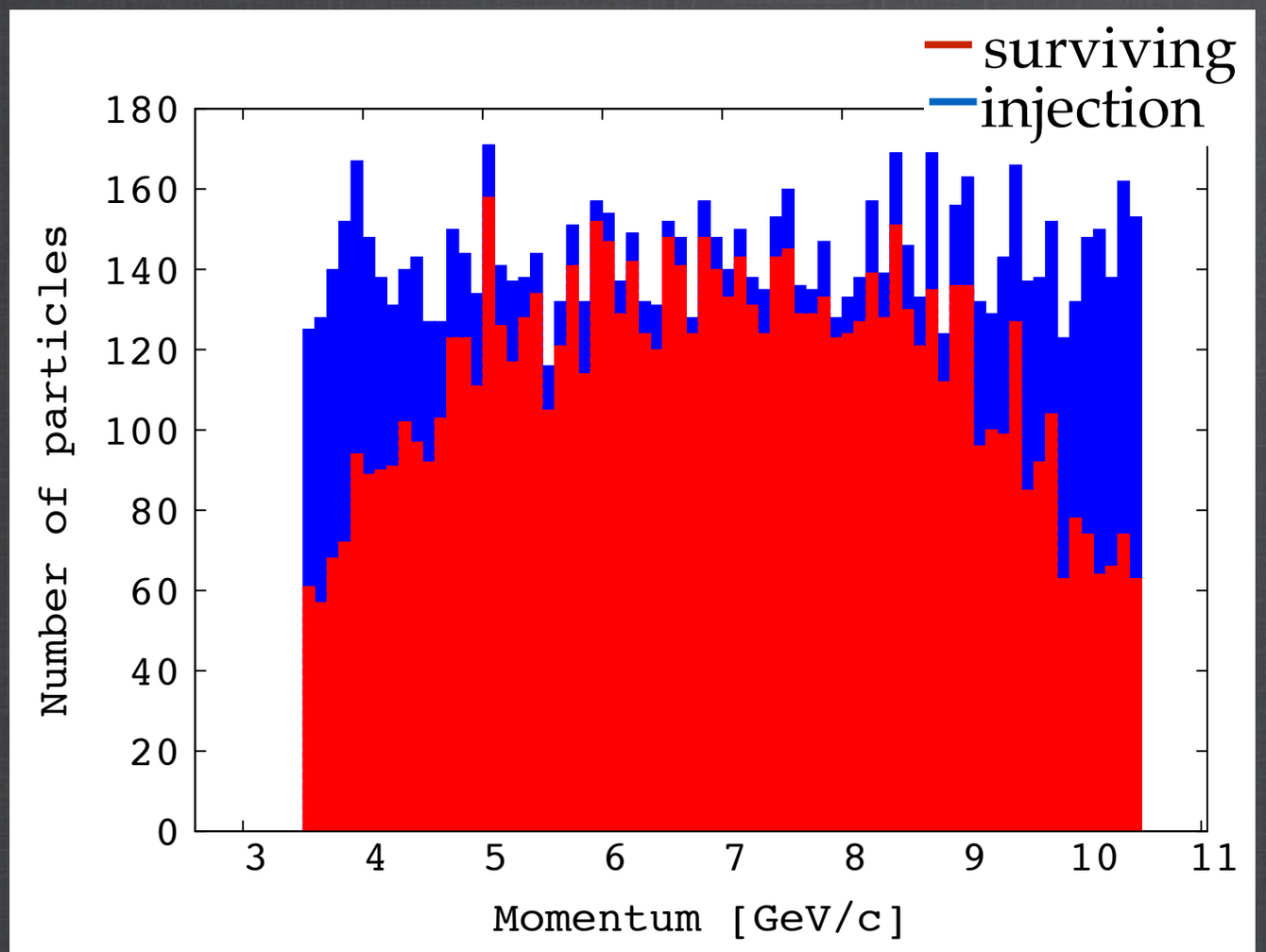
Momentum uniformly distributed around 7 GeV/c **±50%**.



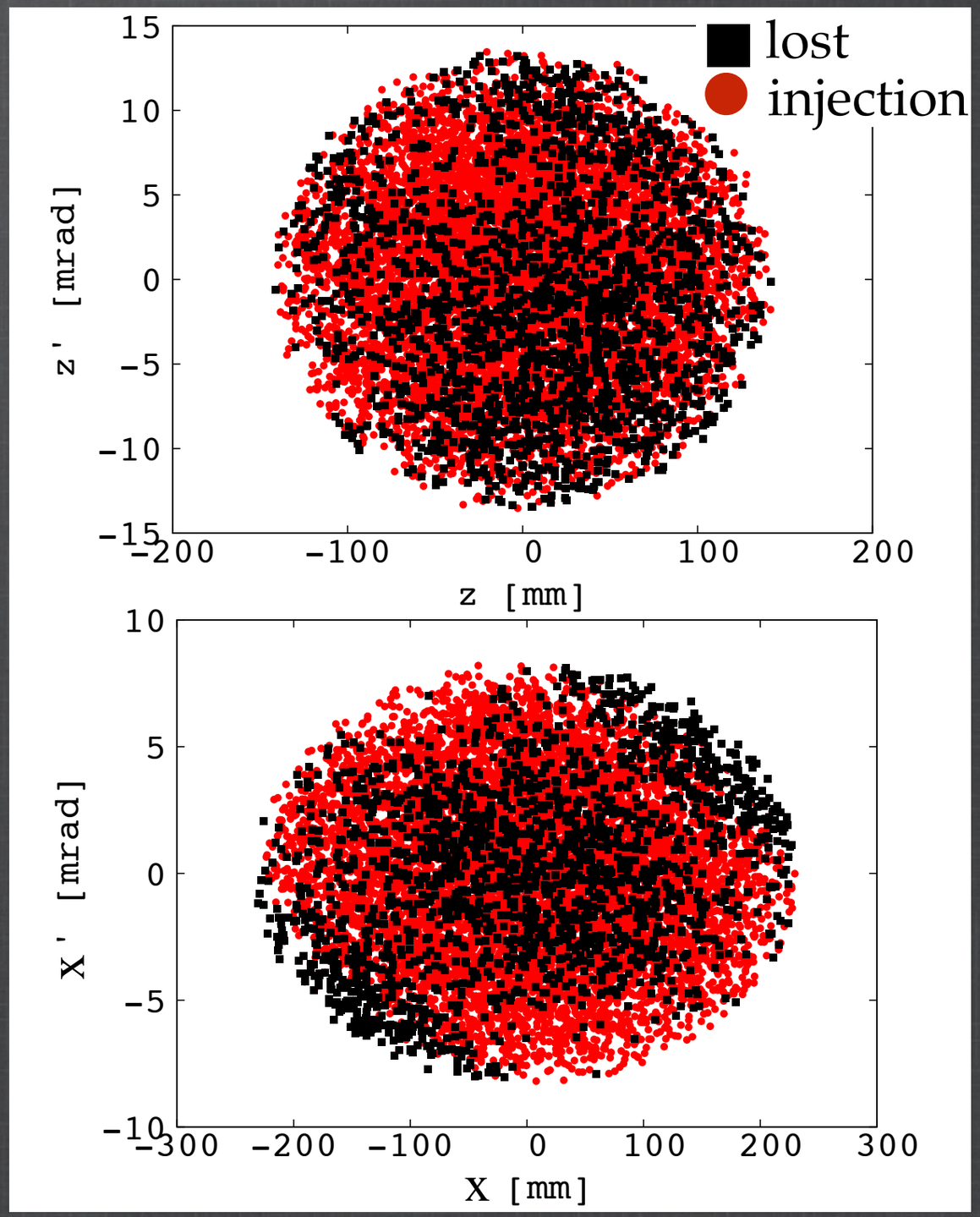
Results in the vertical (left) and horizontal (right) phase spaces

double achromat FFAG beam line

Survival: 80%



Momentum range at the injection (blue) and for the surviving particles (red) after tracking.

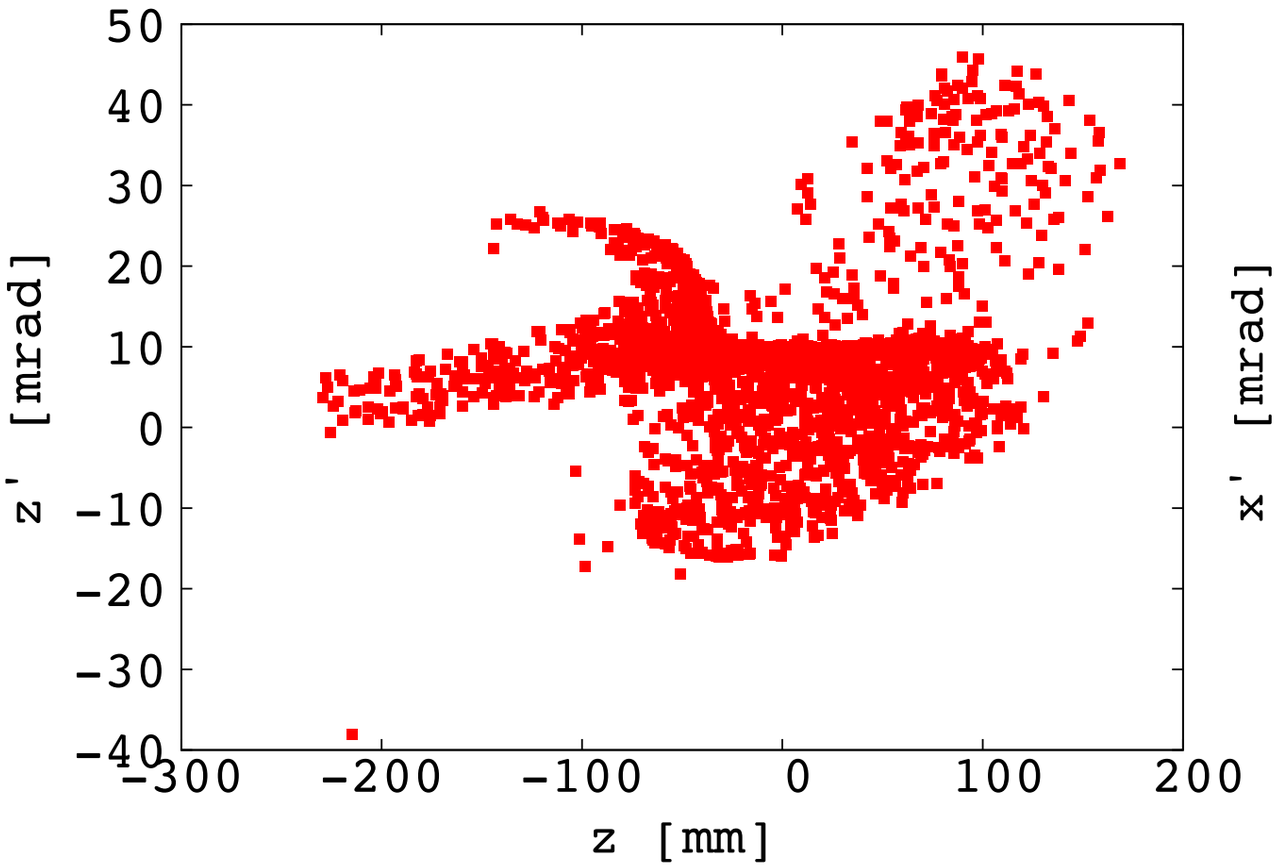


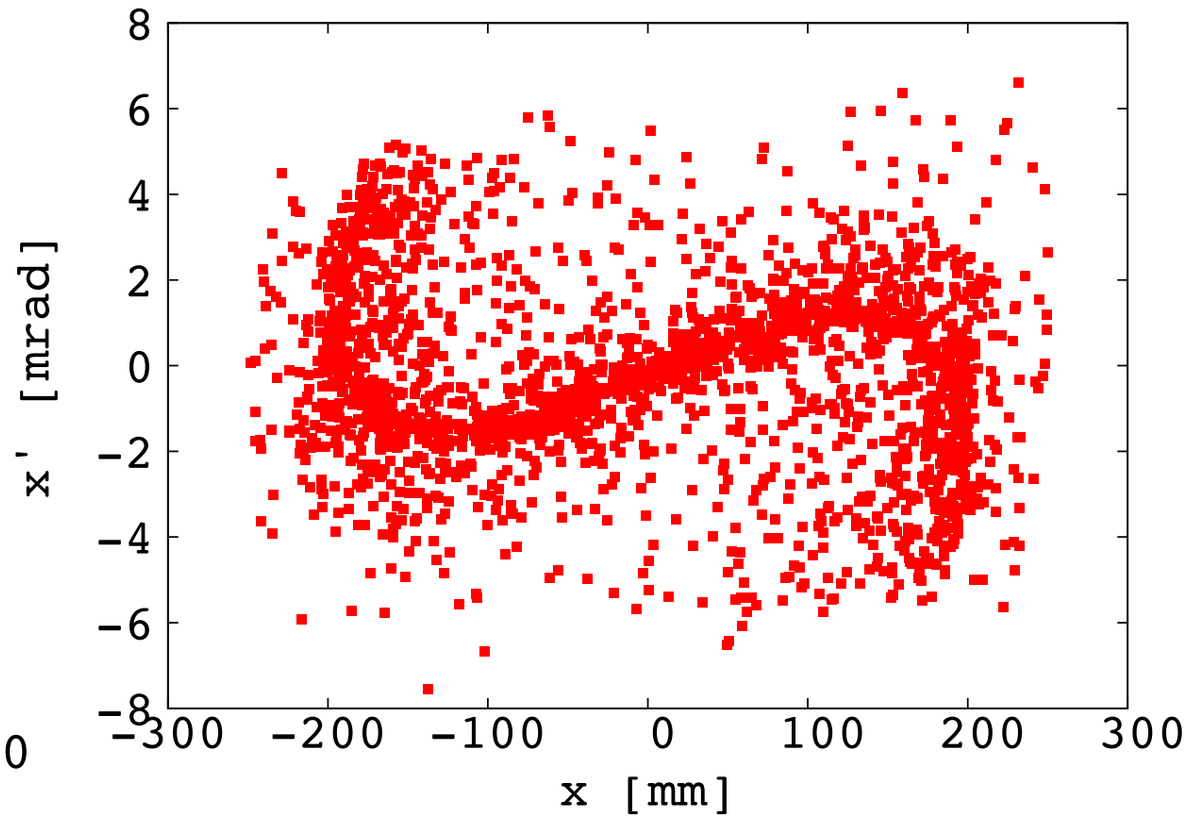
Results in the horizontal (top) and vertical (bottom) phase spaces

double achromat FFAG beam line

Wrong Sign Survival

~1.1 10^6 particles (distribution from the horn) → 2.38% survival



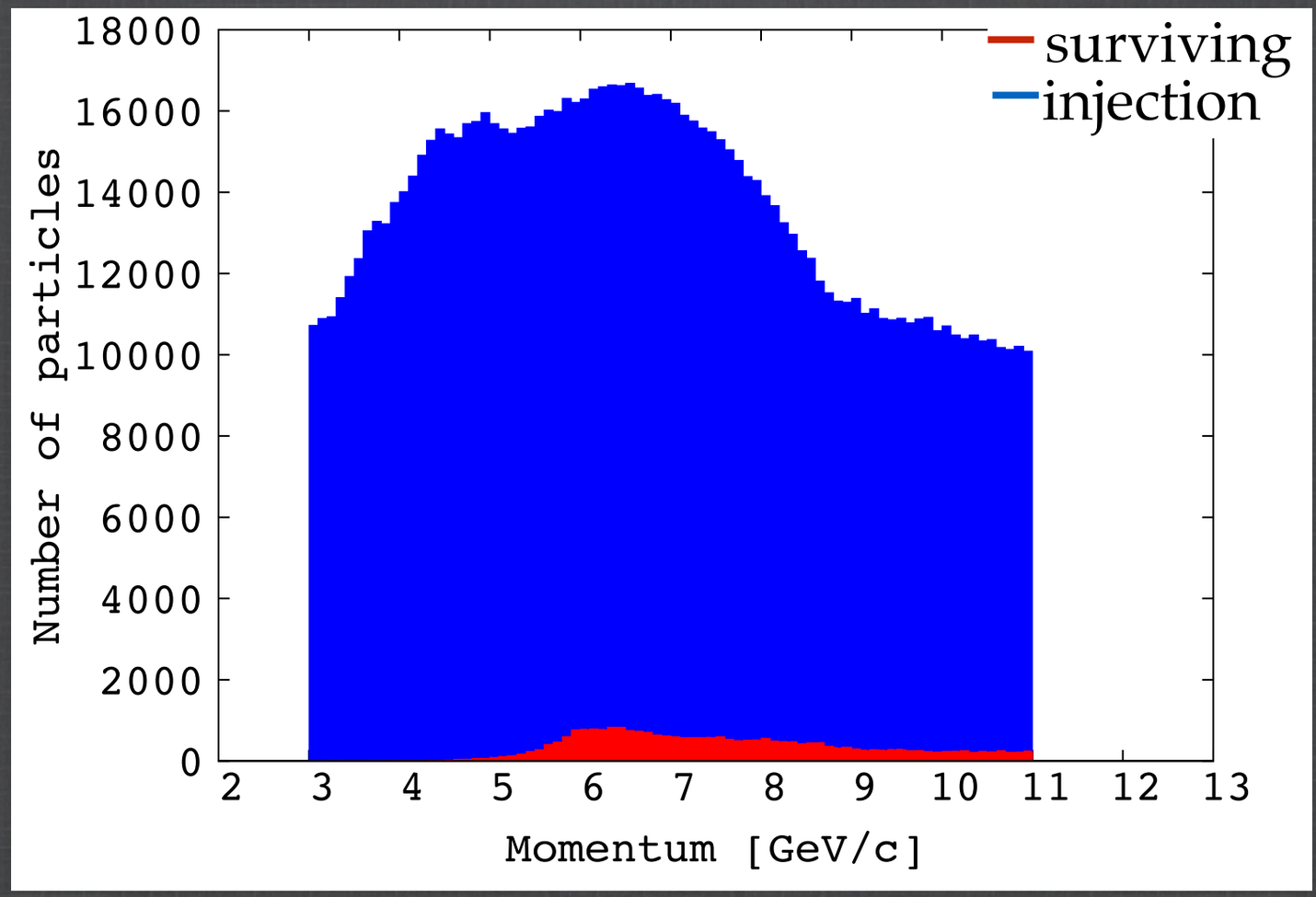


Surviving particles in vertical (left) and horizontal (right) phase spaces

double achromat FFAG beam line

Wrong Sign Survival

~1.1 10^6 particles (distribution from the horn) → 2.38% survival



Momentum range at the injection (blue) and for the surviving particles (red) after tracking.

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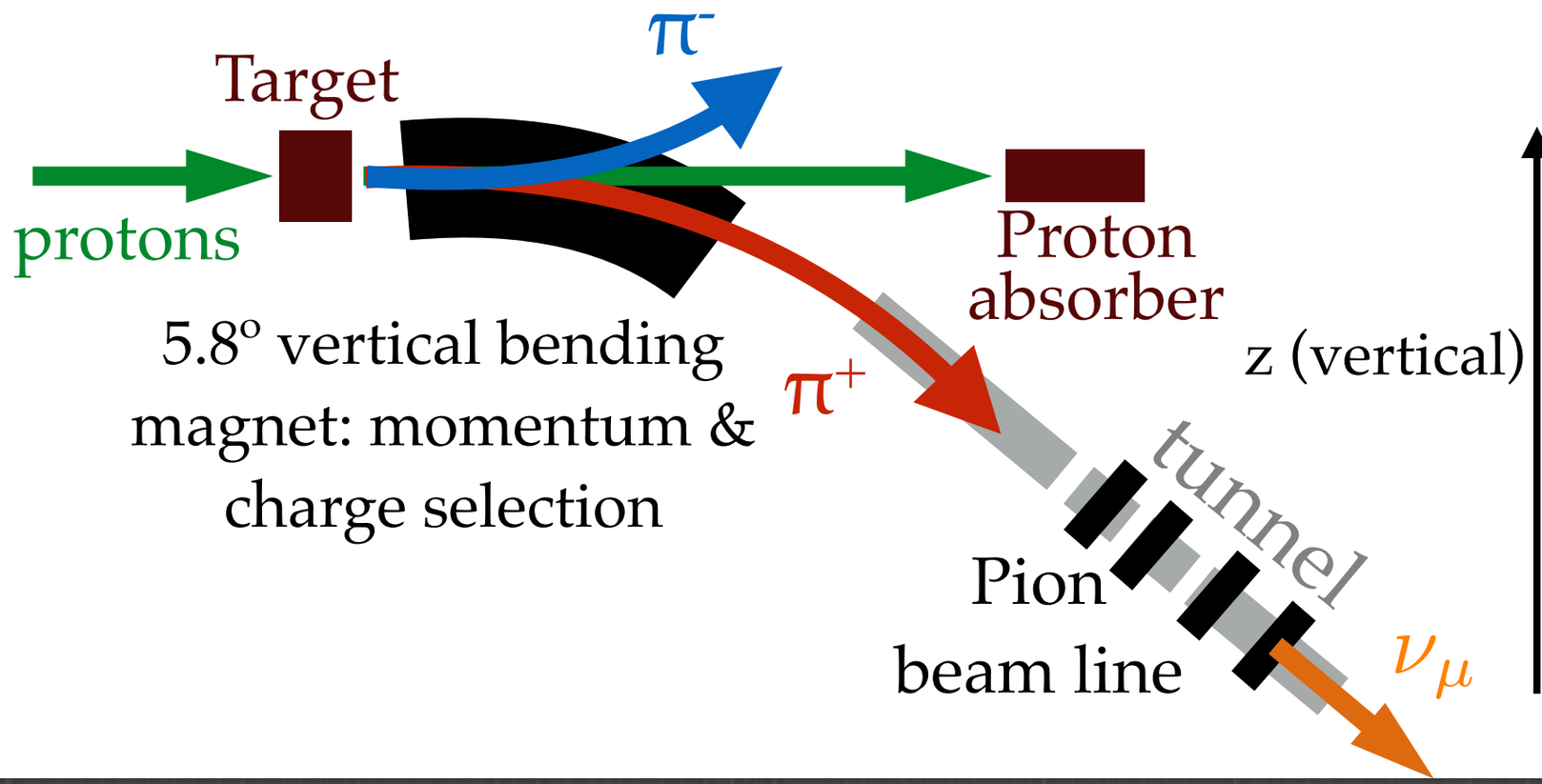
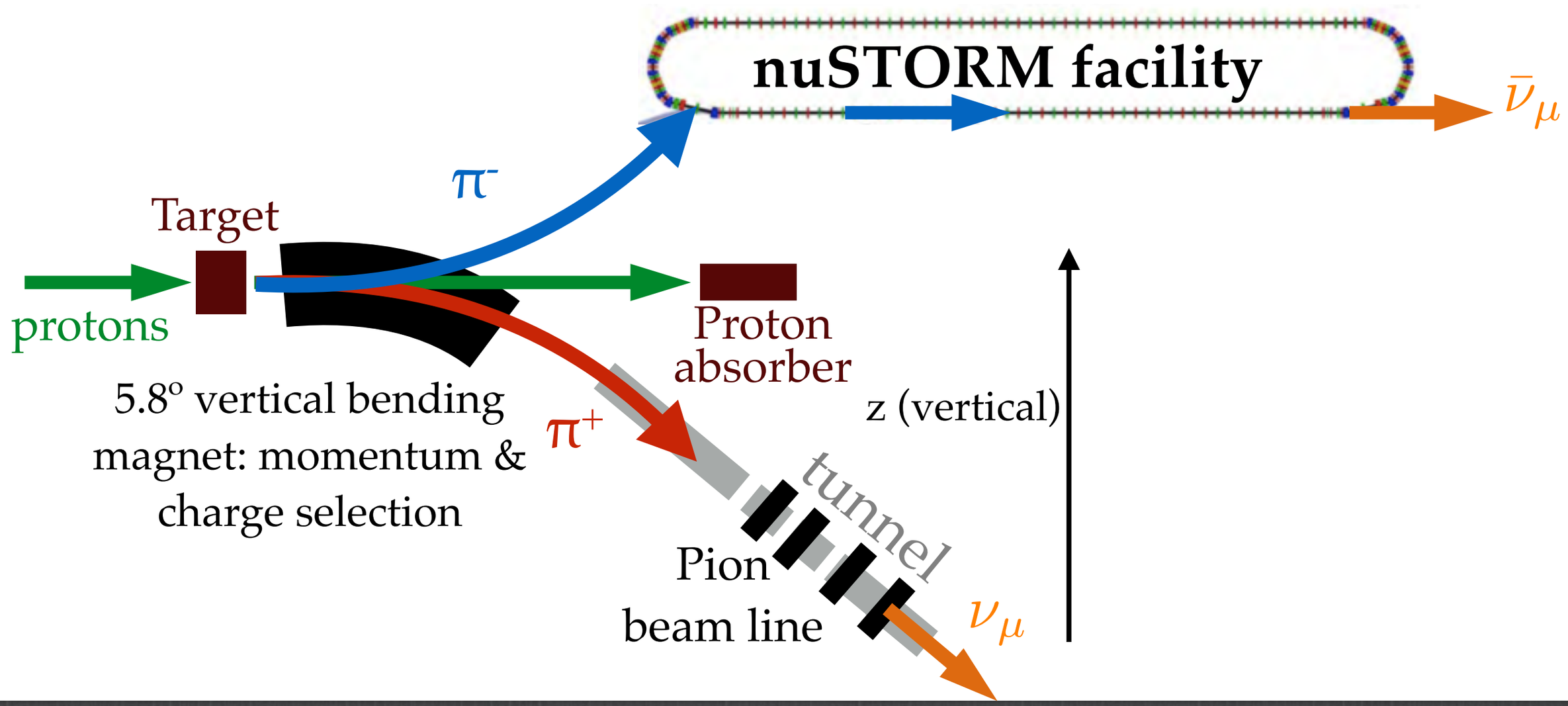
Going even further…

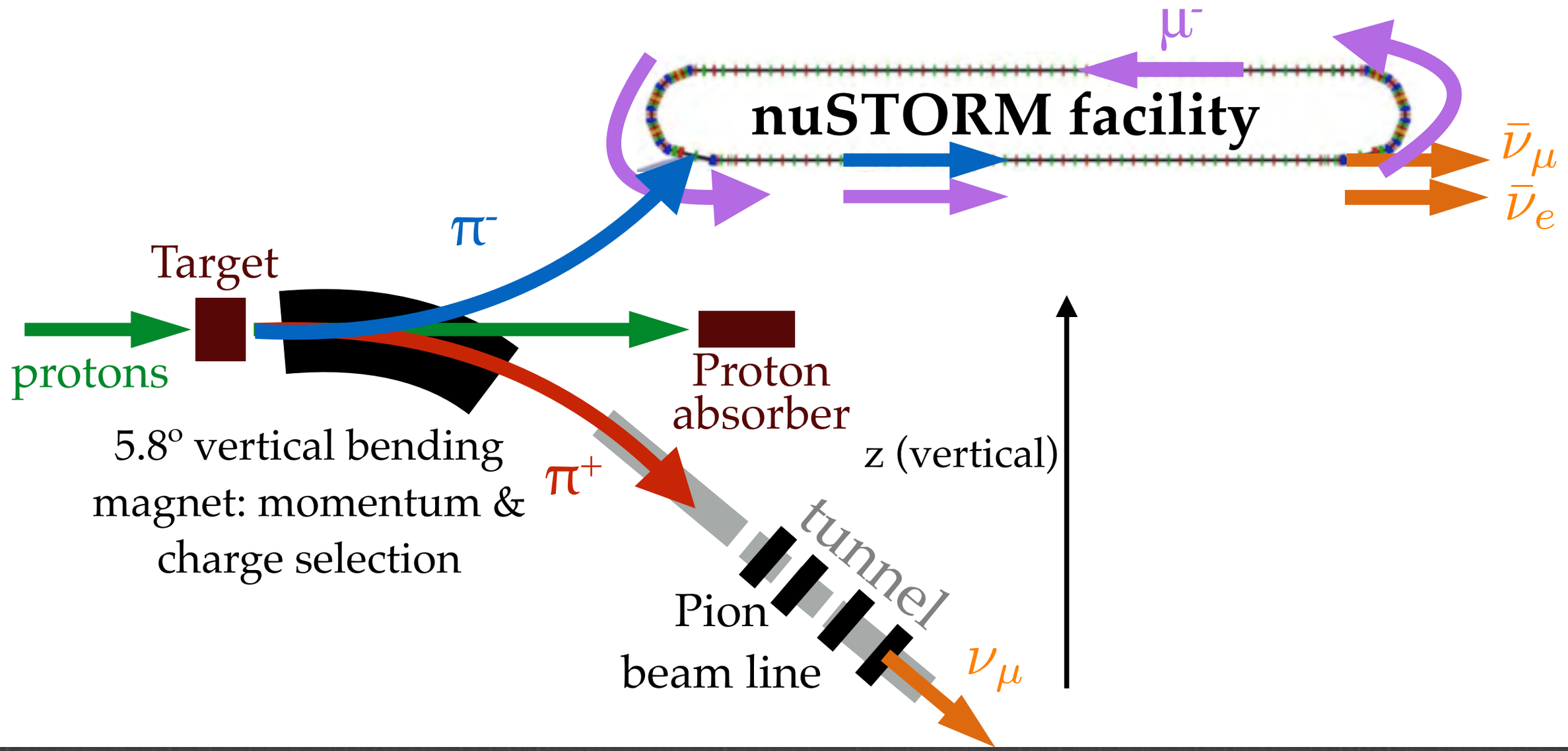


nuPIL AND nuSTORM?



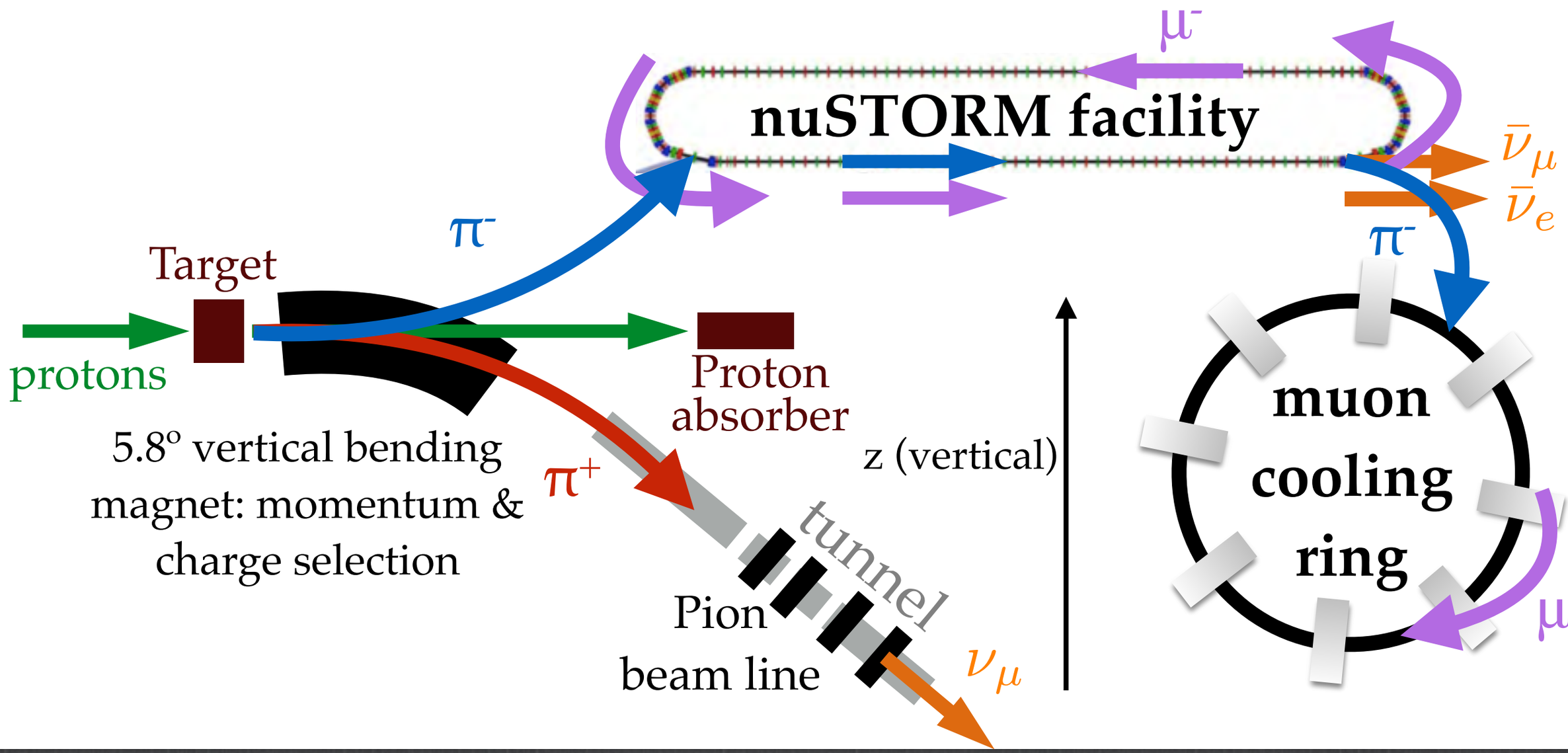
The wrong-sign pions could be used for Short Baseline experiments (i.e. nuSTORM).

nuPIL AND nuSTORM?



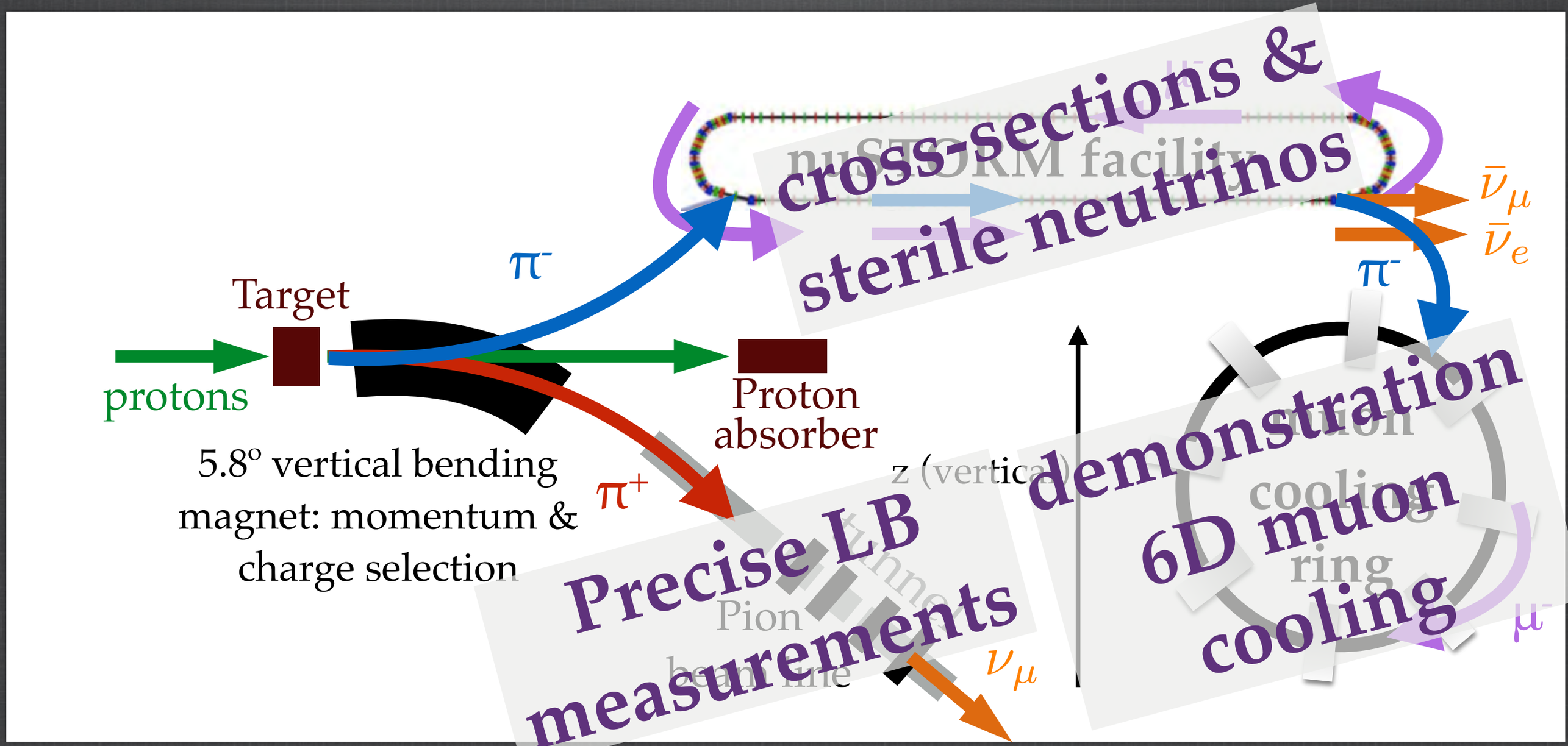
The wrong-sign pions could be used for Short Baseline experiments (i.e. nuSTORM).

Let's be greedy...



Muon cooling experiment (C. Rubbia's ring) could also be implemented!

Let's be greedy...



Muon cooling experiment (C. Rubbia's ring) could also be implemented!

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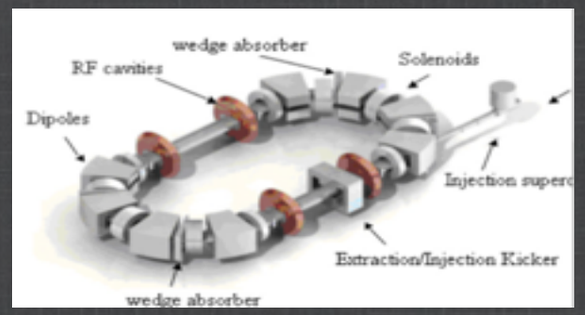
Summary

- Pion beam line has good potential for LB scenario.
  - Clean beam,
  - Well known beam,
  - Comparable flux at 3 GeV for the FODO solution (but drops sharply when energy goes off-peak)
- Different possible designs are investigated.
  - FODO design,
  - Double achromat FFAG and quadrupoles,
  - Single achromat FFAG, straight FFAG dispersion, suppressor and quadrupoles.

Summary

- Preliminary results not too bad, but need improvements.
- Large potential for combined experiments: LB, SB and muon cooling ring demonstration
  - nuPIL
    +
  - nuSTORM
    +
  - muon cooling ring



Future plans

- Compute the flux from the second design.
- Third design concept to be implemented.
- Optimization for all designs, and compare them regarding the final flux at the detector.
- Investigate beam optics for nuSTORM facility.

Thank you for your attention